Accuracy and Utility of Self-Report of Refractive Error: the UK Biobank study

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Conflict of Interest

None of the authors have any conflict of interest to declare.

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ABSTRACT

Importance

Large-scale generic epidemiological studies offer detailed information on potential risk factors for refractive error across the life course, often lacking in ophthalmology-specific studies. However, ophthalmic examination to determine refractive error phenotype is challenging and costly thus, in that context, refractive status is commonly assigned using questionnaires. In a population survey there is often only scope to include a few condition-specific self-reported questions so it is critical that the questions used are effective in both 'ruling in' those who have the trait of interest and 'ruling out' those without it.

Objective

We determined the accuracy of identification of refractive status using self-reported age and/or reason for first wearing optical correction.

Design

UK Biobank study: cross-sectional epidemiological study.

Setting

Six regional centres in England and Wales.

Participants

117,278 participants, aged 40–69 years in 2009/10.

Main outcome and Measures

Subjects had autorefraction measurement of refractive status. Spherical equivalent (SphEqu) on the more 'extreme' eye was used to categorise myopia (SphEqu ≤-1diopter) and hypermetropia (SphEqu ≥+1diopter). Sensitivity and specificity of reason for optical correction were assessed, using autorefraction as the gold-standard. ROC curves assessed the accuracy of self-reported age of first wearing optical correction and incremental improvement with additional information on the reason.

Results

Of those reporting using glasses/contact lenses, 92,121/95,240 (97%) gave age at first use and 93,156 (98%) the reason. For myopia, sensitivity of reason for optical correction was 89.1% [88.7, 89.4], specificity 83.7% [83.4, 84.0] and positive and negative predictive values were 72.7% [72.2, 73.1] and 94% [93.8, 94.2] respectively. The area under the curve (AUC) was 0.829 [0.826, 0.831], improving to 0.928 [0.926, 0.930] with combined information. By contrast self-report of reason for optical correction for hypermetropia had low sensitivity (38.1% [37.6, 38.6]) and the AUC with combined information was 0.71 [0.709, 0.716].

Conclusions and Relevance

In combination, self-report of reason for and age at first use of optical correction are accurate in identifying myopia. These findings indicate an agreed set of questions could be implemented effectively in large-scale generic population-based studies, to increase opportunities for integrated research on refractive error to develop novel prevention or treatment strategies.

Introduction

Refractive error, in particular myopia, is an important public health concern worldwide, as the most common cause of impaired vision and because of the associated risk of blinding complications.[1] The costs of correction (optical or surgical) are high.[2] Striking temporal changes in whole population distribution of refraction have resulted in both increased frequency and severity of myopia in particular: half of the adult population in the United States and Western Europe[3-5] now has refractive error and an even greater majority of Asian populations is myopic.[6]

The challenge for prevention and disease modification now lies in bringing together genetic, classical and lifecourse epidemiological research to elucidate how genetic and environmental risk factors combine to influence risk and severity.[7,8] Such research requires very large general population-based surveys and/or cohort studies with detailed information on potential risk factors across the life course, information which is often lacking in disorder-specific ophthalmic studies. Undertaking a detailed ophthalmic assessment in this context, usually using non-specialist examiners, to determine accurately refractive status is challenging methdologically, time-consuming and costly. An alternative approach has been to elicit refractive status using questionnaires. Although there has been limited research about the validity of self-reported questionnaire data on refraction, it is recognised that accuracy depends on the specific questions asked and whether responses are used singly or in combination.[9,10] We report on the utility of self-report of reason for and age of first wearing any optical correction, separately or in combination, to categorise myopia or hypermetropia in the UK Biobank Study, a contemporary population-based study unparalled for its scale and scope.

Methods

Study population

UK Biobank is a prospective study of health and disease in more than half a million adults recruited between 2006-2010 (http://www.ukbiobank.ac.uk/). From 2009 the protocol included an ophthalmic examination which included non-cycloplegic autorefraction (Tomey RC 5000 auto- refkeratometer, Tomey Corp., Nagoya, Japan) on a subsample of 117,278 (23%) subjects aged between 40 and 69 years of age, as reported elsewhere.[11]

Classification of refractive errors

Spherical equivalent (SphEqu) measurements (algebric sum in dioptres (D), sphere + 0.5 cylinder) were used to categorise refractive error in each eye, with a threshold of ≤-1D for myopia: mild myopia (SphEqu -1.0D to -2.99D), moderate myopia (SphEqu -3.0D to -5.99D), high myopia (SphEqu -6.0D or more extreme), emmetropia (SphEqu -0.99D to 0.99D), mild hypermetropia (SphEqu +1.0D to +2.99D) and moderate/high hypermetropia (SphEqu + 3.0D or more extreme).

Participants answered questions about optical correction (see Box 1).

Box 1.

Lead and follow-up questions	**Response options**
Do you wear glasses or contact lenses to correct your vision?	i) yes, ii) no, iii) prefer not to answer
If Yes: What age did you first start to wear glasses or contact lenses?	i) age in years, ii) do not know, iii) prefer not to answer
If Yes: Why were you prescribed glasses/contact lenses?	i) For short-sightedness, i.e. only or mainly for distance viewing such as driving, cinema etc. (called 'myopia') ii) For long-sightedness, i.e. for distance and near tasks

	like reading (called 'hypermetropia') iii) For just reading/near work as you are getting older (called 'presbyopia') iv) For 'astigmatism' v) For a 'squint' or 'turn' in an eye since childhood (called 'strabismus') vi) For a 'lazy' eye or an eye with poor vision since childhood (called 'amblyopia'), vii) Other eye condition viii) Do not know ix) Prefer not to answer

Statistical methods

Assignment of myopia and hypermetropia by self-reported use of, reason for and age of first wearing optical correction, were validated using spherical equivalent measurement on the more 'extreme' eye (the larger absolute SphEqu difference from zero) as the gold standard. Sensitivity and specificity were calculated for myopia i.e. the proportion of those with SphEqu ≤-1D (i.e. myopic, true positives) who reported myopia as the reason for their optical correction and the proportion of those with SphEqu >-1D (true negatives) not reporting myopia as the reason for optical correction. Positive predictive values (PPV), the proportion of those who self-reported myopia as the reason for wearing glasses who had myopic refraction and negative predictive value (NPV), the proportion of those who did not give myopia as the reason for wearing glasses and did not have myopic refraction, were used to estimate the utility of self-report of myopia. Estimates were similarly calculated for hypermetropia.The Receiver Operating Characteristics (ROC) curves were generated for the age of first use of optical correction (continuous variable) and for the combined variables, reasons for and age of first use of optical correction. The area under the curve (AUC) was used to compare the predictive models. Non parametric Spearman correlation coefficient was used for self-reported age of first spectacle use and refractive error measurements.

Analyses were carried out using Stata,version 13 (StataCorp LP, College Station, Tex., USA).

UK Biobank has approval from the North West Multi-Centre Research Ethics committee, which covers the UK. It also obtained approval in England and Wales from the Patient Information Advisory Group for gaining access to information that would allow it to invite people to participate. PIAG has since been replaced by the National Information Governance Board for Health & Social Care. Recruitment into the UK Biobank study was by written consent.

Results

Participation and study sample

Autorefraction data were available on 107,409 subjects (92% of those invited). Those who did not meet the protocol requirements, were not tested/had no measurement available due to equipment failure (n = 4079), as well as those with prior eye treatment/condition that could affect current refraction, e.g. cataract illness/surgery, or myopia secondary to other ocular condition (n=5058) together with those with highly discordant refraction measures for the two eyes (n = 731) were excluded as described elsewhere[11]. 426 subjects had no information on the use of optical correction. (eFigure 1: Flowchart of participation)

Of those with refraction data, 54.4% were female. The mean age of females was 56.4 years (SD 8.0) and of males was 56.9 years (SD 8.2). 32,165 (30%) subjects had myopia, 34,064 (32%) hypermetropia and 48,180 (38%) emmetropia, (eTable 1).

Accuracy of self-report of reason for spectacle use

Of 107,409 participants, 95,240 (89%) reported wearing glasses/contact lenses. 93,156 (98%) of these reported the reason for wearing glasses; myopia, 37,368 (40%), hypermetropia, 19,646 (21%), or other reasons (e.g. astigmatism or presbyopia) 36,142 (39%), (Table 1).

Myopia

The sensitivity for myopia was 89% [88.7, 89.4], while the specificity was 84% [83.4, 84.0] (Table 2). The predictive positive and negative values for myopia were 72.7% [72.2, 73.1] and 94% [93.8, 94.2] respectively. Of those self-reporting as having myopia 6,573 (18%) were actually emmetropic, median SphEqu -0.5 [-0.8, 0.6], and 3,645 (9.8%) hypermetropic, median SphEqu 2.1 [1.5, 3.1]. The median age of those reporting myopia, although in fact emmetropic, was 58 years [IQR 50-63] with a median age when first wearing optical correction of 30 years [IQR] 18 – 45] and 30% reported wearing glasses for presbyopia as well as myopia. Of those who reported being myopic but were actually hypermetropic, the median age was 63 years [IQR 59-66] with median age when first wearing optical correction of 40 years [IQR 18 – 48] and 43% reported wearing glasses for presbyopia as well.

Hypermetropia

In the group of 19,646 participants self-reporting hypermetropia, the sensitivity of the question on reason for wearing optical correction was 38% [37.6, 38.6], with a higher specificity of 87.8% [87.6, 88.1] (Table 2). Of those self-reporting hypermetropia 5,803 (29.5%) were actually emmetropic, median SphEqu 0.38 [-0.28, 0.70], and 1,649 (8.4%) myopic, median SphEqu -2.4 [-4.5, -1.4] (Table 1). Thus the PPV was 62% [61.4, 62.7] and NPV 73.1 [72.7, 73.4] (Table 2). The median age of those who reported being hypermetropic who were actually emmetropic was 58 years [IQR 51-63] with a median age when first wearing optical correction of 42 years [IQR 25-48] and 16% reported wearing glasses for presbyopia as well as hypermetropia. Those self-reporting hypermetropia who were myopic had a median age of 58 years [IQR 52-63], and reported first having glasses as young people/adults, median 18 years [IQR 12-32]. 125 (7.6%) of this group reported wearing glasses for presbyopia.

Accuracy of self-report of age of first spectacle use

Overall, 92,121 (97%) of study participants reported the age of first wearing optical correction, with 90,307 (95%) reporting both first age of and reason for wearing optical correction.

Myopia

The median first age of use of optical correction for those with myopia was 15 years with interquartile range (IQR) 11 to 22 years (Figure 1a). The median spherical equivalent and IQR in myopes varied by first age of spectacle use from -5.6 D (-8.0 to -3.7) in those under 10 years of age to -1.49 D (-2.07 to -1.20) in those over 40 years (Table 3). There was an association between first age of spectacle use and severity of myopia; 95% of high myopes, 80% of moderate and 47% of mild myopes wore glasses before the age of 20 (Table 3). The majority of those with first age of use of optical correction after the age of 40 had mild myopia.

Hypermetropia

Although the overall median reported for age of first spectacle use for those with hypermetropia was 42 years (IQR 26-49 years), the majority either reported use when under 20 years of age (20%) or between the ages of 40 and 60 years (63%), reflecting either childhood hypermetropia or the onset of presbyopia in mid-life with the associated age-related hyperopic shift in refractive error, with or without pre-existing mild hypermetropia (Figure 1b). In hypermetropes, median SphEqu varied by first age of spectacle use from 4.2D (2.6 to 5.9) in those under 10 years of age to 1.8D (1.3 to 2.4) in those over 40 years. 46% of high/moderate hypermetropes started to wear glasses before the age of 20 years whereas 76% of mild hypermetropes started wearing glasses after 40 years of age (Table 3). The correlation coefficients between age of first use of optical correction and mean spherical equivalent were 0.55 ($p<0.001$) and -0.38 ($p<0.001$), for myopia or hypermetropia respectively.

ROC curves were plotted separately for myopia and hypermetropia (Figure 2a/2c). The area under the curve (AUC) for myopia was 0.829 [0.826, 0.831], a threshold of age of first use of optical correction at age 28 giving the best sensitivity (83.9% [83.5, 84.3]) and specificity (77.3% [77.0, 77.7]) for myopia.

The AUC for hypermetropia was 0.612 [0.607, 0.615] indicating poor prediction of hypermetropia using age of first optical correction use. Similar poor predictive value was obtained plotting ROC curves selecting the participants age of first optical correction use either less than 30 years or 30 years or older, the threshold indicated by the age distribution in those with hypermetropia (eFigure 2a/2c).

Accuracy of self-reported age at first and reason for use of optical correction

The AUC for myopia was improved to 0.928 [0.926, 0.930] with the addition of information on reason for use of optical correction (Figure 2b). Overall, the AUC for hypermetropia was 0.71 [0.709, 0.716] with the additional information (Figure 2d), however, in the subsample of participants with age of first use of optical correction at 30 years or younger, the AUC was 0.781 [0.774, 0.788] (eFigure 2b).

Discussion

In this UK adult population, both self-report of the reason for and age of first wearing glasses were found to have good accuracy for identification of myopia (threshold ≤-1D), compared with spherical equivalent (autorefraction) in the more extreme eye, as the ‘gold-standard’ measure, the accuracy being improved if this information was combined. Overall prediction of hypermetropia was poor, however, the accuracy improved when only those aged 30 years or younger at age of first wearing glasses were included.

We found an association between age of first wearing glasses, used as a proxy for age of onset, and severity of both myopia and hypermetropia, which is consistent with prior research. [12] Further direct comparison with other studies is not straightforward because of the use of either different direct or indirect questions to elicit reasons for use of optical correction or examination of prescribed distance glasses to identify those with refractive error and use of either prescription data or auto/refraction measures as the gold-standard. In addition, there is no consensus in epidemiological studies on optimal definitions of myopia/hypermetropia which impacts on both prevalence and sensitivity/specificity estimation.[6,9,10,13,14]

Despite the scale and size of UK Biobank, there are some limitations. Identification of refractive error based on self-report of *prescribed* optical correction meant that those with undiagnosed (and therefore 'untreated') refractive error would be missclassified. However, in the UK those with undiagnosed refractive error in this age group, are likely to have mild late-onset myopia, as are those who wore glasses previously but no longer required them, thus the majority of those with a primary refractive error will have been identified by the lead question on use of glasses/contact lenses. Refractive error status in individuals was assigned based the more extreme eye to avoid misclassification of those with anisometropia which occurs when using the *mean* spherical equivalent of two eyes. Finally, the self report questions used in Biobank were intended to categorise refractive status as a categorical variable, in keeping with norms in classical and lifecourse epidemiology. It would be necessary to have separate questions asking about reason for *first* use of optical correction and for *current use* in order to be able to take refractive shift (hypermetropic or myopic) in later adult life into account. In genetic epidemiology there is advantage in analysing refraction as a quantitative trait but self-report could nevertheless be useful as a means of identifying subjects eligible for further detailed assessment.

Ten percent of those reporting wearing glasses for myopia actually had hypermetropia and conversely 8% of those reporting glasses for hypermetropia were myopic. Over 20% of ‘misclassified’ myopes and hypermetropes were older adults who also reported wearing glasses for presbyopia which could have led to some confusion in their reports on reason for their *current* prescription and in addition there may have been a small number of individuals who simply reported incorrectly in error. The majority of those misclassified had mild refractive error and reported first wearing glasses as young adults, rather than during childhood. Thus, the wording of questions in this survey, with an explanation of terms, identified the majority of those with primary myopia and more severe hypermetropia.

Sensitivity and specificity of self-report for the indentification of myopia in the present study were comparable with those reported in two prior studies using similar questions.[13,15] Those studies included younger adults, had lower thresholds for definition of myopia (≤-0.5D and <0D) and used the subject’s worn spectacle prescription as the gold standard rather than measuring actual refraction [13] (sensitivity 89% and 83%, specificity 83% and 93%, respectively). Accuracy of self-report for identification of hypermetropia has consistently been found to be poor, [10,13,15] with specificity of self-report of reason for glasses generally higher than sensitivity. However, high specificity does not compensate for low sensitivities when self-report is used as a ‘screening tool’ in population studies to identify participants for further assessment.

We have previously reported that physical examination of glasses by non-expert examiners to assign lenses as ‘magnifying’ or ‘minimising’ is effective in categorising (but not quantifying) refractive status;[10] but is limited by the need for additional data collection time and training of non-specialist assessors and failure to capture undiagnosed refractive error or sole contact lens use. Spectacle prescription data have also been used to validate self-report of refractive status[13] but is susceptible to bias in those with available data and the time-lag between testing and report of prescription as well as the clinical scenario in which a prescription is intentionally different to the actual refraction. Sensitivity of self-report is lowest for questions using lay rather than technical terms i.e. 'short'- and 'long'-sightedness: respondents appear to find this confusing, leading to high misclassification rates.[9,10] Interestingly, parental report of eye problems and diagnosed eye disorders in their children can include accurate medical terminology and lead to prevalence estimates directly comparable with clinical studies.[16] Patient/parents' use of the internet to research suspected or diagnosed conditions has meant their use of medical terminology is more widespread.[17] Notably we and others[12] have found age of first wearing glasses - a proxy for age of onset- to be associated with severity of both myopia and hypermetropia. Thus using self-report of age at first use of optical correction combined with self-report of refractive error status is likely to be the most effective method for identifying myopia and hypermetropia (though less effectively) in the new generation of large-scale general population studies in health care settings similar to UK Biobank in which refractive correction is avalable.[18] It is critical that the questions selected are effective in both 'ruling in' those with the trait of interest and 'ruling out' those without it so that self report defines phenotype sufficiently well to harness the power of scale.[19,20] The next step is to improve the predictive value of self report by considering variations by potential predictors of the refractive error phenotypes. We are taking this forward within our programme on eyes and vision within CLOSER, the UK Cohort and Longitudinal Studies Enhancement Resources initiative (http://www.closer.ac.uk/).

Conclusion

Using self-report questions on the reason for use and age of first wearing optical correction, and ideally a combination of the two, is a feasible and accurate way to identify those with myopia in an adult population. This approach is less accurate for hypermetropia. The utility of self-report of refractive error relates to the nature of the research and the degree to which any misclassification would impact and is dependent on the precise wording of the questions. There is scope to develop an agreed set of questions that could be implemented effectively in large-scale generic population based studies, so as to increase the opportunities for the integrated research on refractive error necessary to develop novel prevention or treatment strategies.

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Contributors

JSR and PMC conceived and designed the study. AC and PMC conducted the statistical analysis and interpreted the data. All authors contributed to the drafting and revision of manuscript.

AC and PMC had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Role of the Funder

The funding organizations had no role in the design or conduct of the study; in the collection, management, analysis, and interpretation of the data; in the preparation, review or approval of the manuscript; or in the decision to submit the manuscript for publication.

Conflict of Interest

None of the authors have any conflict of interest to declare.

Figure titles

Figure 1 Distribution of age of first wearing glasses/contact lenses by refractive error by myopia and hypermetropia

Figure 2 Receiver operating characteristic (ROC) curve for sensitivity and specificity for age and age and reason at first optical correction use in identifying myopia or hypermetropia

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Table 1: Categorization of refractive error status; self-report versus spherical equivalent (autorefraction measure)

		Refractive error category (spherical equivalent measure)		
N=93,156	n (%)	Myopia (SE≤1D)	Emmetropia (SE>-1 to <+1D)	Hypermetropia (SE≥1D)
Self-reported refractive error				
Myopia only	30,855 (82.6)	24,266 (78.6)	4,550 (14.8)	2,039 (6.6)
Myopia & presbyopia	6,292 (16.8)	2,746 (43.7)	1,978 (31.4)	1,568 (24.9)
Myopia and other*	221 (0.6)	138 (62.4)	45 (20.4)	38 (17.2)
Myopia (overall)	*37,368 (40.1)*	*27,150 (72.7)*	*6,573 (17.6)*	*3,645 (9.8)*
Hyperopia only	14,196 (72.2)	1,224 (8.6)	4,398 (31.0)	8,574 (60.4)
Hyperopia & presbyopia	232 (1.2)	19 (8.2)	72 (31.0)	141 (60.8)
Hyperopia & presbyopia& astigmatism	2,447 (12.5)	97 (4.0)	843 (34.4)	1,507 (61.6)
Hyperopia & astigmatism	1,400 (7.1)	223 (15.9)	344 (24.6)	833 (59.5)
Hyperopia & other**	1,371 (7.0)	86 (6.3)	146 (10.6)	1,139 (83.1)
Hyperopia (overall)	*19,646 (21.1)*	*1,649 (8.4)*	*5,803 (29.5)*	*12,194 (62.1)*
Other reasons***	*36,142 (38.8)*	*1,676 (4.6)*	*18,309 (50.7)*	*16,157(44.7)*
Total		*30,475*	*30,685*	*31,996*

* other = astigmatism/strabismus/amblyopia/other ** other = strabismus/amblyopia/other ***any reason other than myopia or hypermetropia

Table 2: Sensitivity and specificity of myopia or hypermetropia in those who self-reported on wearing optical correction

	Sensitivity	Specificity	Positive predictive value	Negative predictive value
	%	%	%	%
	95% Confidence Interval	95% Confidence Interval	95% Confidence Interval	95% Confidence Interval
Reason for wearing glasses / contact lenses *n=93,156*				
Myopia	89.1 (88.7 to 89.4)	83.7 (83.4 to 84.0)	72.7 (72.2 to 73.1)	94.0 (93.8 to 94.2)
Hypermetropia	38.1 (37.6 to 38.6)	87.8 (87.6 to 88.1)	62.1 (61.4 to 62.7)	73.1 (72.7 to 73.4)
*Wear glasses "no" and reason for w*earing glasses / contact lenses *n=104,899*				
Myopia	85.7 (85.3 to 86.1)	86.0 (85.8 to 86.3)	72.7 (72.2 to 73.1)	93.3 (93.1 to 93.5)
Hypermetropia	37.0 (36.5 to 37.5)	89.6 (89.4 to 89.9)	62.1 (61.4 to 62.7)	75.7 (75.4 to 75.9)

Table 3: Distribution of refractive error (spherical equivalent in more extreme eye) by severity and age of first wearing optical correction

			Myopia							
			Spherical Equivalent (D)							
Age group in years	n	%	median	IQR	High n	High %	Moderate n	Moderate %	Mild n	Mild %
<10	4,607	15.3	-5.63	(-7.98 to -3.72)	2,124	40.3	1,700	15.4	783	5.6
10 to <20	15,819	52.4	-3.74	(-5.38 to -2.41)	2,883	54.7	7,211	65.4	5,725	41.1
20 to <30	5,043	16.7	-2.40	(-3.48 to-1.65)	209	4.0	1,525	13.8	3,309	23.8
30 to <40	1,998	6.6	-1.85	(-2.65 to -1.38)	29	0.6	328	3.0	1,641	11.8
40 to <50	1,815	6.0	-1.51	(-2.15 to-1.22)	18	0.3	173	1.6	1,624	11.7
50 to <60	839	2.8	-1.43	(-1.91 to -1.18)	2	0.04	71	0.6	766	5.5
60 to <70	96	0.3	-1.58	(-2.14 to -1.14)	2	0.04	11	0.1	83	0.6
Total	30,217		-3.23	(-5.13 to -1.91)	5,267		11,019		13,931	
Missing	1,948		-1.63	(-2.48, -1.22)	88		289		1,571	

			Hypermetropia					
Age group in years	n	%	median	IQR	Mild n	Mild %	Moderate/High n	Moderate/High %
<10	3,376	10.7	4.16	(2.56 to 5.88)	1,058	4.5	2,318	29.0
10 to <20	3,060	9.7	2.67	(1.60 to 4.35)	1,735	7.3	1,325	16.6
20 to <30	1,823	5.8	2.40	(1.55 to 3.86)	1,133	4.8	690	8.6
30 to <40	2,597	8.2	2.30	(1.56 to 3.49)	1,701	7.2	896	11.2
40 to <50	13,173	41.7	1.82	(1.36 to 2.56)	11,110	47.0	2,063	25.8
50 to <60	7,049	22.3	1.66	(1.30 to 2.24)	6,391	27.0	658	8.2
60 to <70	541	1.7	1.59	(1.27 to 2.11)	506	2.1	35	0.4
Total	31,619		1.97	(1.41 to 3.02)	23,634		7,985	
Missing	2,445		1.77	(1.29, 2.68)	1,968		477	